# NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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REPORT No. 328

# WATER PRESSURE DISTRIBUTION ON A TWIN-FLOAT SEAPLANE

By F. L. THOMPSON



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## AERONAUTICAL SYMBOLS

### 1. FUNDAMENTAL AND DERIVED UNITS

| | Symbol | Metric | | English | |
|---|---|---|---|---|---|
| | | Unit | Symbol | Unit | Symbol |
| Length | $l$ | meter | m | foot (or mile) | ft. (or mi.) |
| Time | $t$ | second | sec | second (or hour) | sec. (or hr.) |
| Force | $F$ | weight of one kilogram | kg | weight of one pound | lb. |
| Power | $P$ | kg/m/sec | | horsepower | HP. |
| Speed | | km/hr | | mi./hr | M. P. H. |
| | | m/sec | | ft./sec | f. p. s. |

### 2. GENERAL SYMBOLS, ETC.

$W$, Weight, $=mg$

$g$, Standard acceleration of gravity $=9.80665$ m/sec.$^2=32.1740$ ft./sec.$^2$

$m$, Mass, $=\frac{W}{g}$

$\rho$, Density (mass per unit volume).

Standard density of dry air, 0.12497 (kg-m$^{-4}$ sec.$^2$) at 15° C and 760 mm $=0.002378$ (lb.-ft.$^{-4}$ sec.$^2$).

Specific weight of "standard" air, 1.2255 kg/m$^3=0.07651$ lb./ft.$^3$

$mk^2$, Moment of inertia (indicate axis of the radius of gyration, $k$, by proper subscript).

$S$, Area.

$S_w$, Wing area, etc.

$G$, Gap.

$b$, Span.

$c$, Chord length.

$b/c$, Aspect ratio.

$f$, Distance from $c.\ g.$ to elevator hinge.

$\mu$, Coefficient of viscosity.

### 3. AERODYNAMICAL SYMBOLS

$V$, True air speed.

$q$, Dynamic (or impact) pressure $=\frac{1}{2}\rho V^2$

$L$, Lift, absolute coefficient $C_L=\frac{L}{qS}$

$D$, Drag, absolute coefficient $C_D=\frac{D}{qS}$

$C$, Cross-wind force, absolute coefficient $C_C=\frac{C}{qS}$

$R$, Resultant force. (Note that these coefficients are twice as large as the old coefficients $L_C$, $D_C$.)

$i_w$ Angle of setting of wings (relative to thrust line).

$i_t$, Angle of stabilizer setting with reference to thrust line.

$\gamma$, Dihedral angle.

$\rho\frac{Vl}{\mu}$, Reynolds Number, where $l$ is a linear dimension.

e. g., for a model airfoil 3 in. chord, 100 mi./hr. normal pressure, 0° C: 255,000 and at 15° C., 230,000;

or for a model of 10 cm chord 40 m/sec, corresponding numbers are 299,000 and 270,000.

$C_p$, Center of pressure coefficient (ratio of distance of $C.\ P.$ from leading edge to chord length).

$\beta$, Angle of stabilizer setting with reference to lower wing, $=(i_t-i_w)$.

$\alpha$, Angle of attack.

$\epsilon$, Angle of downwash.

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U. S. GOVERNMENT PRINTING OFFICE: 1929

# NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

NAVY BUILDING, WASHINGTON, D. C.

(An independent Government establishment, created by act of Congress approved March 3, 1915, for the supervision and direction of the scientific study of the problems of flight. It consists of 15 members who are appointed by the President, all of whom serve as such without compensation.)

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By F. L. Thompson

### SUMMARY

*The investigation reported herein was conducted by the National Advisory Committee for Aeronautics at the request of the Bureau of Aeronautics, Navy Department. This is the second of a series of investigations to determine water pressure distribution on various types of seaplane floats and hulls, and was conducted on a twin-float seaplane. It consisted of measuring water pressures and accelerations on a TS–1 seaplane during numerous landing and taxiing maneuvers at various speeds and angles.*

*The results of this investigation show that water pressures as great as 10 lbs. per sq. in. may occur at the step in various maneuvers and that pressures of approximately the same magnitude occur at the stern and near the bow in hard pancake landings with the stern well down. At other parts of the float the pressures are less and are usually zero or slightly negative for some distance abaft the step. A maximum negative pressure of 0.87 lb. per sq. in. was measured immediately abaft the step. The maximum positive pressures have a duration of approximately one-twentieth to one-hundredth second at any given location and are distributed over a very limited area at any particular instant. The greatest accelerations measured normal to the thrust line at the c. g. occurred in pancake landings, and a maximum of 4.3 g. was recorded. Approximate load distribution curves for the worst landing conditions are derived from the data obtained to serve as a guide in static tests.*

### INTRODUCTION

There is but little known concerning the magnitude and distribution of water pressures on seaplanes when landing or taxiing on either smooth or rough water. Consequently, the size and arrangement of structural members that make up a seaplane float are based on experience with previous successful designs rather than on definite information as to the forces to be encountered. Floats that are undamaged in operation are sufficiently strong, but knowledge of the actual water pressures encountered is needed before structural weight can be safely reduced to a minimum.

At the request of the Bureau of Aeronautics, Navy Department, a series of investigations to determine water pressures on various types of seaplane floats are being made. The investigation reported herein is the second in this series and was conducted on a twin-float seaplane. The first investigation was conducted on the UO–1 single-float seaplane and has been previously reported. The third investigation is to be conducted on a boat-type seaplane.

A TS–1 twin-float seaplane was used, and positive water pressures were measured at 15 stations on the outboard half of one float bottom. Subsequent to the positive pressure measurements, negative pressures were determined at five points abaft the step and one forward. The apparatus used for measuring positive pressures was the same as that used in the previous investigation (reference 1), with some minor changes. Additional instruments were used to record accelerations normal to the thrust line at the *c. g.* of the seaplane and to measure, approximately, accelerations of the float bottom.

The tests included numerous taxiing and landing runs at various speeds and attitudes except that negative pressure measurements were confined to take-off runs. Simultaneous records of the water pressures at all stations, the air speed, float angle, and acceleration were

obtained. The average wind velocity was also determined with an anemometer while testing was in progress so that the water speed could be computed.

This report includes a brief description of the instruments and apparatus used in the tests, a description of the test procedure, the results obtained and conclusions reached. The complete data are presented in tables and are summarized by a table and curve showing the distribution of maximum pressures over the float bottom. In addition, there are curves showing the manner in which water pressures act on the float bottom and approximate load distributions for hard pancake landings.

## APPARATUS AND METHOD

### APPARATUS

These tests were conducted on a TS–1 twin-float seaplane. (Fig. 1.) It is a single-place biplane that may be equipped with either floats or wheels. As a seaplane it has a specified gross

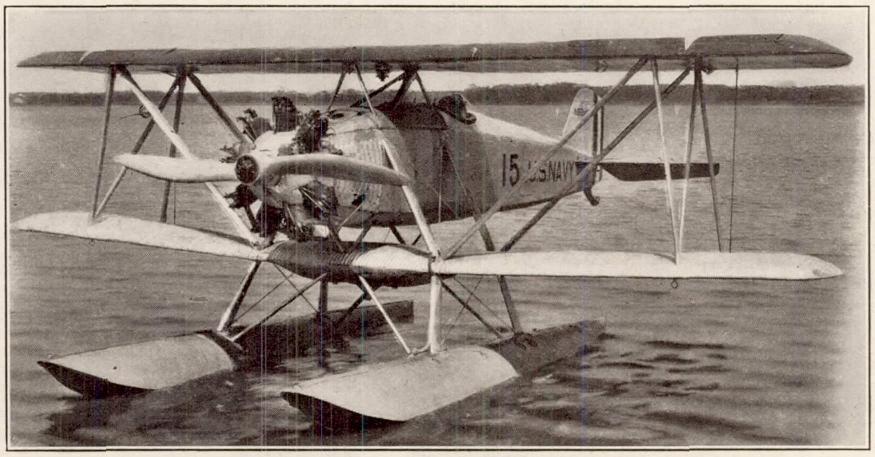



FIGURE 1.—TS–1 seaplane on which the tests were conducted

weight of 2,123 pounds. The weight of the research equipment used in the tests was such that it was necessary to reduce the fuel load one-half to keep the gross weight as specified. It was found that the landing speed was from 60 to 65 M. P. H. for a normal landing.

The floats are of wooden construction and are shaped as shown in Figure 2. The step is 2 inches high at the keel; the angle of the after keel is 5½°; and a line from the bottom of the step to the stern makes an angle of 7° with respect to the deck line. The deck line is parallel to the

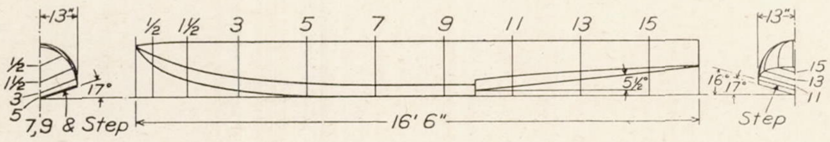



FIGURE 2.—TS–1 float lines

thrust axis and wing chords. The angle of V is 17° at the bottom of the step and increases slightly toward the bow giving a fairly flat entry. Abaft the step the angle of V is 16°. Negative pressures were measured on a float of slightly modified shape. The principal differences are in the step which is three inches high, and the after keel angle, which is 4°.

The research equipment included the following instruments and apparatus:

1. A single-component recording accelerometer.
2. A float angle observer.
3. Two recording manometers.
4. A swiveling Pitot-static air-speed head.
5. A motor-type electric timer.
6. A 4-element plunger-type accelerometer.
7. Water-pressure apparatus, positive and negative.

1. A description of the N. A. C. A. single-component recording accelerometer is given in reference 2. This instrument records optically the deflection of a weighted cantilever spring. The component of acceleration normal to the thrust line was measured with this instrument during each run of the positive pressure tests.

2. Longitudinal float angles were recorded by photographing the shore line parallel to the path of the seaplane with a small, motor-driven motion-picture camera rigidly mounted in the fuselage. Five images per second were obtained.

3. Two recording manometers with two pressure cells each were used. An instrument of this sort with one pressure cell is described in reference 3 as the recording element of an N. A. C. A. recording air-speed meter. It records optically the deflections of a diaphragm actuated by the pressure to be measured. One of the four pressure cells thus provided was used to record air speed in these tests. The other three were used to record pneumatic pressures used with the water pressure apparatus.

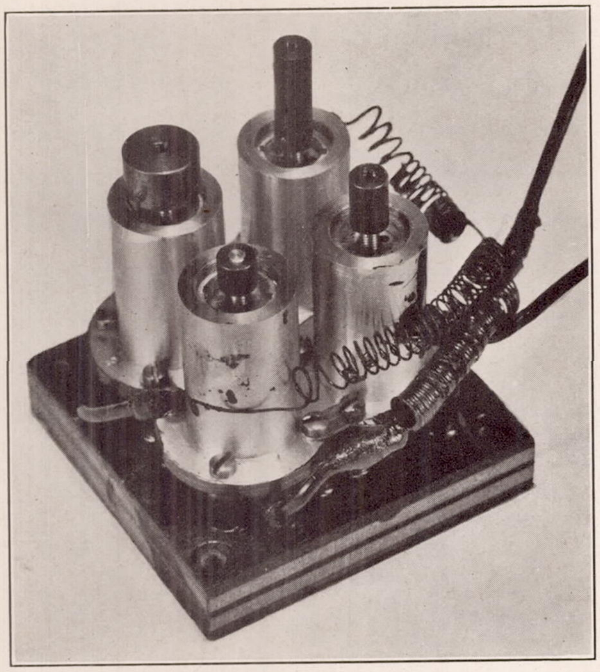


FIGURE 3.—Plunger-type accelerometer

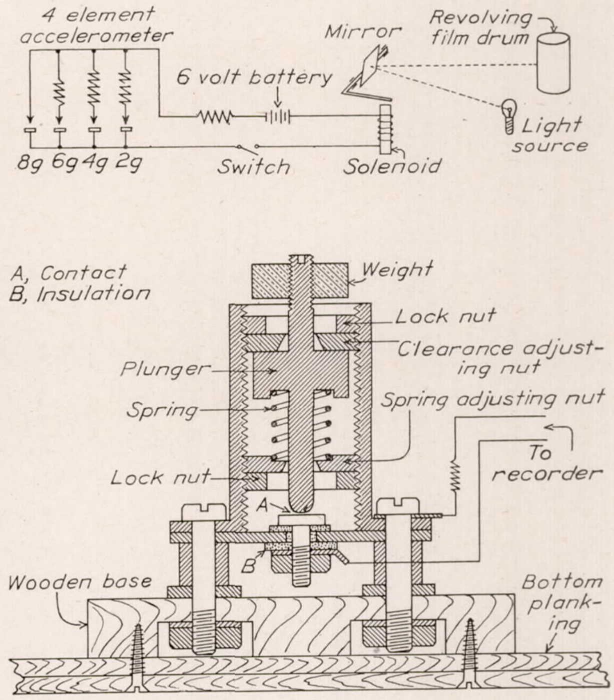



FIGURE 4.—Cross section of one element of accelerometer and diagram of recording circuit

4. The swiveling Pitot-static air-speed head was located on a forward wing strut and was connected to the air-speed recording pressure cell mentioned above.

5. Records were synchronized by timing lines at 1-second intervals with an N. A. C. A. motor-type electric timer. An N. A. C. A. chronometric timer and the method of using it are described in reference 4. The difference in these two instruments is only in the means employed to obtain periodic electrical contacts.

6. A plunger-type accelerometer with four elements was used to measure, approximately, the acceleration of the float bottom planking. This was primarily for the purpose of determining the proper correction to apply to recorded water pressures for the effect of acceleration of the water-pressure units. A photograph of this instrument is shown in Figure 3. It is similar in principle to the accelerometer designed by Doctor Zahm. (Reference 5.) A cross section drawing of one element and a diagram of the recording circuit and mechanism are given in Figure 4. The four elements are similar but respond to different accelerations. The variation in sensitivity is obtained by varying the plunger weight and spring pressure. The elements

were calibrated centrifugally, on a whirling table, and were adjusted to respond to accelerations of $2g$, $4g$, $6g$, and $8g$, respectively. The record obtained is a line broken in steps which indicate the number of plungers making contact. To insure proper accuracy in recording short-period accelerations, the contact clearance was set at 0.003 inch. The instruments was made as small and light as practicable and weighed but 0.6 pound when ready for installation. It was mounted on the right side of the bottom of the left float about 15 inches forward of the step and in the center of an unsupported bottom planking area.

7. A detailed description of a water-pressure unit and the complete apparatus used in recording water pressures is given in reference 1. The water-pressure units operate on a principle of opposing the force due to water pressure on one end of a piston by a force due to a known pneumatic pressure on the other end. When the water force exceeds the pneumatic force the piston makes an electric contact which is indicated in an optical record by deflection of the record line. Four such pistons in each unit respond to different water pressures and cause different deflections. The range of pressures recordable depends on the pneumatic pressure which can be varied as desired. Fifteen of these pressure units were installed in the left side and seven in the right side of the bottom of the left float, as shown in Figure 5. As the water-pressure recorder accommodates but 15 pressure units, all those on the left side were first connected. The remaining seven units were to be connected later to determine if an appreciable difference in pressure existed between the two sides of the float bottom. This was not done, however, since the floats were in very bad condition at the completion of the tests with the first 15 units.

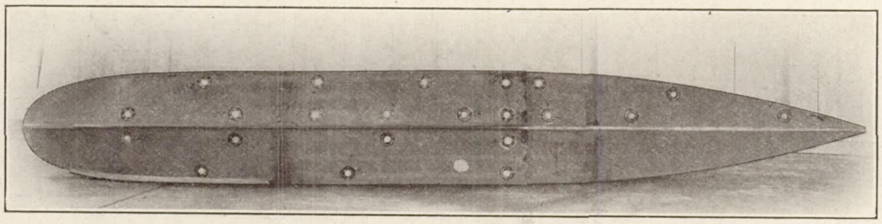


FIGURE 5.—TS-1 float bottom with pressure units installed

The only essential difference between the installation used in these tests and that used formerly, as described in reference 1, is in the connection of all pressure unit recording circuits in parallel to a 6-volt storage battery instead of using independent circuits with a 1.5-volt dry cell for each one. The electrical circuit for each pressure unit is similar to that of the plunger-type accelerometer shown in Figure 4. When this accelerometer was used it was connected to the water pressure recorder in place of one of the water-pressure units.

Negative water pressures were recorded with two 2-pressure-cell recording manometers as described above. They were connected to one-eighth inch diameter orifices in the float bottom by metal tubing. Five orifices were located abaft the step and one immediarely forward, all on the same side of the float bottom. Each manometer accommodated two orifices, so that only four orifices at a time could be connected.

The general arrangement of the instrument installation is shown in Figures 6, 7, and 8. The water-pressure recorder is conspicuous in Figure 6. Two storage batteries are carried in the forward compartment over the group of recording instruments which are shown more clearly in Figure 7. Figure 8 shows the pilot's cockpit. The gauges, dial, and hand pump are parts of the apparatus used in adjusting the pneumatic pressure applied to the water-pressure units. One switch on the instrument board and one by the throttle control were operated when making a run. The latter switch could not be left on more than three seconds, which made it necessary to judge accurately the exact time to operate it when landing.

With instruments and installation as thus described, continuous records, synchronized at 1-second intervals, were obtained during each run. The length of the run, when measuring positive water pressures, was limited to three seconds or less by the nature of the recording

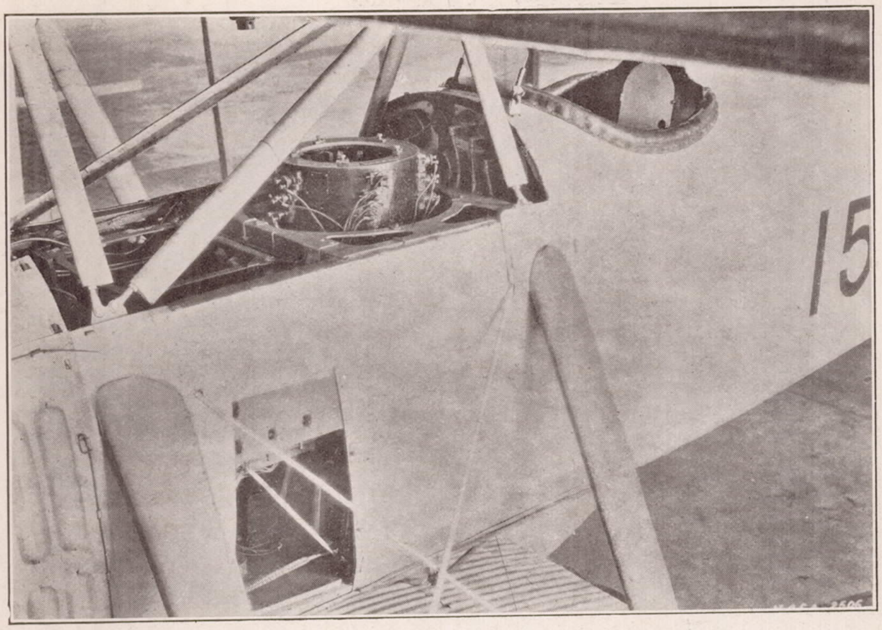


FIGURE 6.—General view of the instrument installation in the TS-1 seaplane

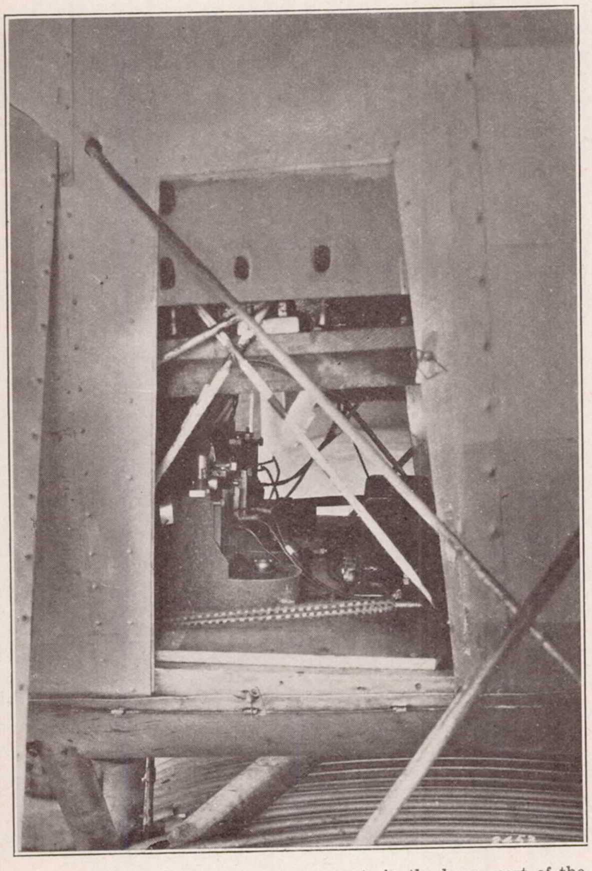


FIGURE 7.—Group of recording instruments in the lower part of the fuselage

arrangement. In the negative pressure tests the length of the records was not limited to so short a period and continuous records of complete take-off runs were obtained. Air speed, longitudinal float angle, acceleration, and water pressures were measured simultaneously during each run, with the exception that during negative pressure tests, acceleration records were not obtained. Positive water pressures were measured at all 15 stations simultaneously, and negative pressures were recorded at six orifices in all, with only four connected at any one time.

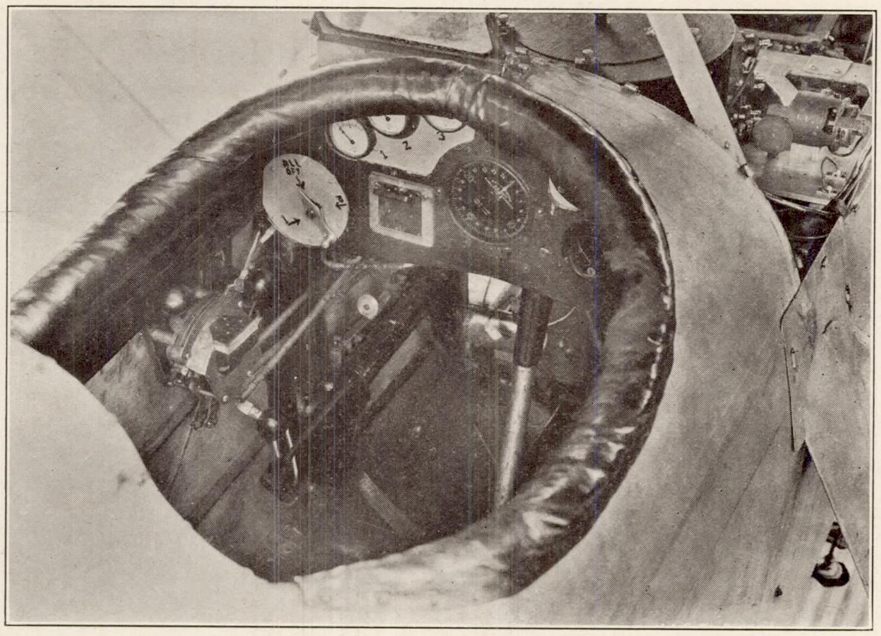


FIGURE 8.—Interior of the cockpit

## METHOD

The maneuvers included taxiing at various attitudes and speeds up to get-away, stalled landings with power off and power on, fast landings, pancake landings, and porpoising. Negative pressures were measured during take-offs with the control back, neutral, and forward, respectively. Each negative pressure run was continuous from opening of the throttle to get-away. The actual get-away when taking off with the control neutral or forward was accomplished by pulling the control back. The pancake landings were made by stalling at a very high angle several feet above the water. The seaplane showed a pronounced tendency to porpoise, particularly when decelerating after landing, and water pressures were therefore measured during this maneuver.

The wind velocity was determined with an anemometer while making tests so that the approximate water speed could be obtained from the air-speed record. The tests were all made in sheltered water where the maximum waves encountered were not more than 15 inches high. The pancake and fast landings developed pressures which damaged the float bottom so maneuvers in rough water were not attempted. The pancake landings caused high local pressures to occur over nearly the entire length of the float and also large total loads with the maximum resultant force applied well forward of the *c. g.* This is probably similar to the effect of encountering large waves, although the direction or magnitude of the resultant force caused by waves might be such as to cause greater stresses in the structure, particularly if the waves were not met head-on.

Both floats were cracked at the step during the tests. The right one was in poor condition at the start and was damaged in a fast landing. The left float cracked in a pancake landing. A landing made while making negative pressure trials was unintentionally hard and ruined both floats, making it necessary to replace them both for the negative pressure tests.

## PRECISION OF RESULTS

The accuracy with which water pressures are recorded is discussed thoroughly in reference 1. The two chief sources of error, as shown therein, lie in the effect of acceleration on the movable pistons of the pressure units, and in the method of bracketing the true pressure between limits of a pressure exceeded and one not exceeded. The error caused by acceleration may be corrected if the acceleration is known. The error due to bracketing is dependent on the closeness of the pressure limits which varies for different pressure units. The true pressure should be considered as the mean of the limits. For a representative case, the difference between the mean and the limits was found to be about 9 per cent of the mean, but the accuracy of the mean for any particular case must be found from the actual limiting pressures determined. A maximum correction for acceleration should be based on an acceleration of approximately 4 *g*, as determined with an accelerometer in the float bottom. The computed maximum correction to be added to the recorded pressure limits is then approximately one-fourth pound per square inch.

The maximum pressures corrected as above are probably correct within less than $\pm 10$ per cent.

The air-speed measurement is estimated to be accurate within $\pm 1$ M. P. H.

The accuracy of the water-speed measurement depends on the accuracy of the air speed and the accuracy with which the average wind velocity represents the actual wind velocity when a run is made. The accuracy is estimated to be within $\pm 4$ M. P. H.

The float-angle values are correct within $\pm \frac{1}{2}°$.

The accuracy of the negative pressure measurements is within $\pm 2$ per cent.

The accelerations at the *c. g.* are considered to be accurate within $\pm 0.1$ *g*.

The acceleration of the float bottom can only be approximated since it was determined by limiting accelerations between values 2 *g* apart. The limits themselves have negligible errors

## RESULTS

### POSITIVE PRESSURES

The maximum pressures recorded during each run are given in Table I, accompanied by a description of the maneuver, the air speed, longitudinal float angle, maximum acceleration, condition of the water surface, and the approximate water speed. The locations of the pressure stations are shown in a figure accompanying the table. For some stations the highest pressure exceeded is not accompanied by an upper limit of pressure not exceeded. Where both limits are given the true maximum pressure is considered to be the mean of the limits plus a correction of one-fourth pound per square inch for acceleration of the pressure unit, as mentioned in the discussion of precision. Where only the lower limit is given the true maximum is considered to exceed this limit by three-fourth pound per square inch, which includes the correction for acceleration and an assumed value of one-half pound per square inch based on a study of the complete data and the limits that were established at other stations. The five highest true pressures at each station are given in Table II with each pressure corrected as above, although it is probable that the correction for acceleration is slightly excessive in some cases, which would make the tabulated pressures a little greater than the actual pressures experienced for such cases. The maximum pressure for each station as given by this table was used in plotting the curve of Figure 9, which shows the distribution of maximum pressures over the float bottom.

The highest pressures occurred in pancake landings, very fast landings, and in fast taxiing runs. The highest vertical accelerations, 4.3 *g* and 3.8 *g*, occurred in pancake landings. Accelerations in excess of 3 *g* also occurred in fast landings, and in one porpoising run in 12 to 15 inch waves. In the latter run the acceleration was 3.4 *g*; the water pressures, however, were not obtained. The worst distribution of pressures occurred in the pancake landings. In these maneuvers the float angle was large and the rate of descent was high. The result was high pressure at the stern followed by high pressure at the step and later at the bow. The reason for

this wide distribution of high pressures was the rotation of the seaplane caused by the force abaft the *c. g.* and subsequently retarded by a force forward of the *c. g.* The shape of the float and the location of the *c. g.* were such that the retarding force was developed suddenly by a high pressure near the bow. During other maneuvers very high pressures were confined to a region extending forward from the step a short distance. The distribution of maximum pressures given by the curve of Figure 9 therefore closely represents the distribution in a severe pancake landing.

The maximum pressures which have been discussed do not occur simultaneously over the entire float bottom, but are confined to a small portion of the bottom at any particular instant, and last only one-twentieth to one one-hundredth second. In a few cases it has been possible to determine accurately the duration and to trace the progress of pressure in excess of a certain value as it travels over the float bottom. The duration and travel of the high pressure can then be shown by curves as described below.

The operation of the first piston of a water-pressure unit indicates that the water pressure has exceeded the minimum pressure which the pressure unit will record with the particular internal pneumatic pressure used. The elapsed time during which this piston remains against

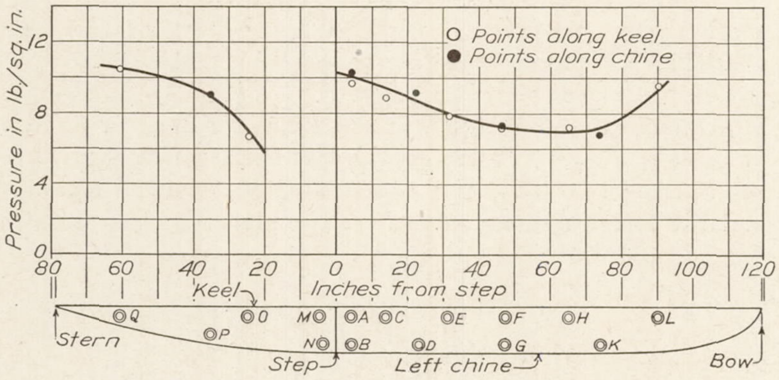



FIGURE 9.—Distribution of maximum water pressures on the float bottom

its contact represents the duration of the water pressure in excess of that minimum. The relative time at which the first piston of each pressure unit operates is determined from the water-pressure record. These values are used as ordinates in plotting a curve with distance of the stations from the step as abscissas. Separate curves are drawn for stations along the keel and along the chine. To these ordinates increments are added which represent the duration of the pressure in excess of the minimum which each unit will record. Two pairs of curves are thus obtained; one represents the travel and duration of pressure in excess of a certain minimum along the keel, and the other does the same for stations along the chine. The difference in time between the start of high pressure at the keel and chine at a given abscissa represents the lag in transverse distribution of pressure due to the V bottom.

The procedure, as described above, was followed for two severe pancake landings, runs 55 and 56. The resulting curves are shown in (A) and (B) of Figures 10 and 11. The lag in transverse distribution of pressure is noticeable in these curves. The minimum pressure recordable was approximately 5 to 6 pounds per square inch for all stations during both of these runs, and the curves therefore represent the travel and duration of pressure exceeding 5 to 6 pounds per square inch. At some stations this minimum pressure was not exceeded and the pressure travel curves, therefore, could not be drawn for the portion of the bottom represented by these stations.

In addition to the high pressure concentrated on a small area at a particular instant, there is also a smaller sustained pressure over a large area to consider. The fluctuations in pressure in a small fraction of a second are usually much greater than the range of pressures that the pressure units will record at one setting of the internal pneumatic pressure. It is therefore

necessary to determine the highest pressures for a maneuver in one run with the internal pressure set for a high pressure range, and the low sustained pressures in a repetition of the maneuver with the internal pressure set for a lower recording range. A study of the records on which low pressures are recorded gives a basis for an assumption as to the sustained pressure to expect over a large area while a concentrated high pressure exists at any given location.

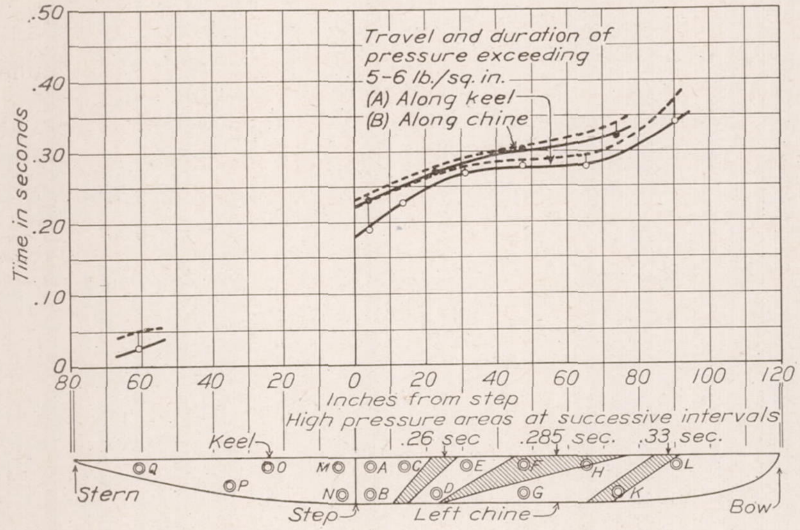



FIGURE 10.—Travel of high local pressure over the float bottom in pancake landing, run 55. Water speed 48 M. P. H., smooth water

A sustained pressure which continued for at least one-fourth second after the high pressure had passed the stations was recorded at stations C, D, and H during pancake landing run 44. This landing was similar to the pancake landings, runs 55 and 56, for which the pressure travel curves are given, with the exception that it was made on water with 10 to 12 inch waves and

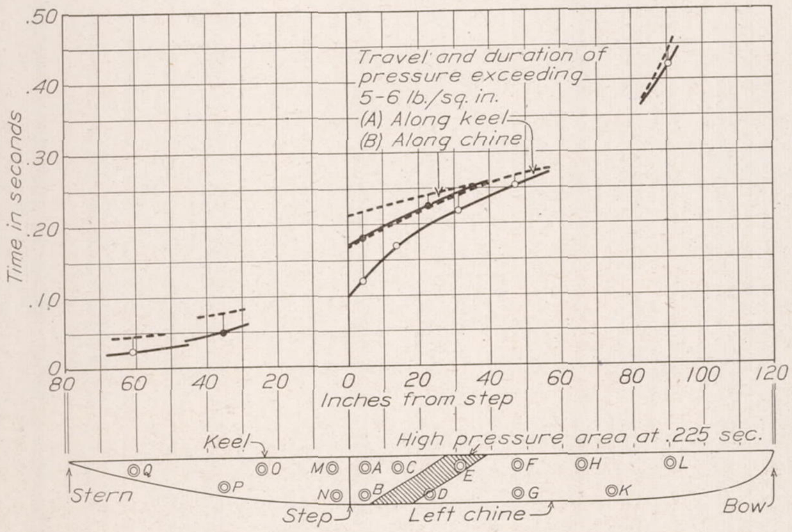



FIGURE 11.—Travel of high local pressure over the float bottom in pancake landing, run 56. Water speed 47 to 42 M. P. H., smooth water

at 10 M. P. H. less water speed. The highest recorded acceleration at the *c. g.* (4.3 *g*) was obtained in this run and the float bottom was damaged at station B. The sustained pressure was 4.3 to 5.7 pounds per square inch at C, in excess of 4 pounds per square inch at D, and 2.8 to 4.1 pounds per square inch at H. At the same time it was less than 3.1 pounds per square inch at A, 4.5 pounds per square inch at B, 4.3 pounds per square inch at E, and 2.5 pounds per square

inch at stations F, G, K, and L. During other maneuvers large sustained pressures were recorded at some other stations. At station A, 5.3 pounds per square inch was almost continuously exceeded, and at B 5.4 pounds per square inch was intermittently exceeded during taxiing run 24. During taxiing run 20 a sustained pressure of 2.4 to 3.1 pounds per square inch was recorded at station F, and in taxiing run 21 a sustained pressure of 3 to 3.9 pounds per square inch existed at E. Station O, abaft the step, indicated a sustained pressure of 2.1 to 3.5 pounds per square inch during taxiing run 15 while at P during the same run 2.1 pounds per square inch was only exceeded intermittently. In each of these taxiing runs the location of the sustained pressure was dependent on the attitude of the float. The pancake landing is particularly important by reason of the high local pressure which travels from the stern to the bow and the large total load indicated by the acceleration at the *c. g.* It appears permissible to assume for this maneuver that a sustained pressure of 3 pounds per square inch exists over the bottom from the step forward to the position of the high-pressure area at any instant. From results obtained in the negative pressure tests, discussed later, it is considered that the pressure abaft the step is negligible when the high pressure is forward.

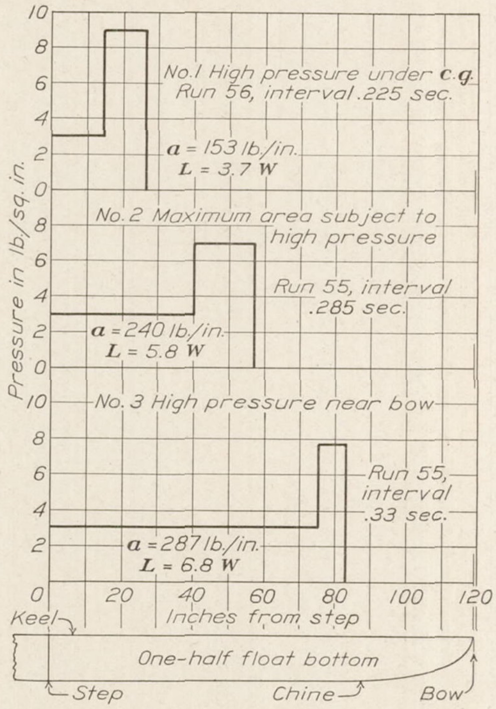



FIGURE 12.—Approximate loads at three intervals for a severe pancake landing

Without records which show the exact simultaneous pressures over the entire float bottom it is impossible to determine an actual load distribution accurately. It is possible, however, to arrive at a probable load distribution from a study of the high local pressures and the low sustained pressures measured for the same maneuvers but on different runs. The sustained pressures likely to prevail in a severe pancake landing have been discussed above. The area subject to high pressure at a given instant in a pancake landing is determined from the pressure-travel curves.

The intersections of a time ordinate with the pressure-travel curves (A) and (B) of Figures 10 and 11 determine four abscissas which are projected down to their respective positions on the lines of the keel and chine stations. These four points determine two sides of the area subject to pressure in excess of 5 to 6 pounds per square inch, which is bounded by the keel and chine on the other two sides. The actual magnitude of the pressure in this area is determined from the pressures given by the maximum pressure distribution curve of Figure 9. The areas subject to high pressure, as thus determined, are shown by the shaded areas in Figures 10 and 11 on one-half the projected float area. The intervals are chosen to show the areas when the high pressure is under the *c. g.*, in the middle of the forebody, and near the bow. In the middle of the forebody the high pressure area is a maximum, although the pressure is not. The projected area is used because only vertical loads are considered. The boundary lines of the areas are not perpendicular to the keel because of the lag in transverse distribution of pressure.

A rectangular representation of the load distributions at three successive intervals during a pancake landing is given in Figure 12. The high pressure at a given instant is represented by a rectangle with a height equal to the pressure on the area in pounds per square inch. The width is that of an area equivalent to the actual area subject to high pressure as given in Figures 10 and 11, but with sides perpendicular to the keel. It is found by dividing the actual high-pressure area by the width of one-half the float. The lower sustained pressure is represented by another rectangle with a height representing a pressure of 3 pounds per square inch and a

width extending forward from the step to the high-pressure area. The combined areas of these two rectangles multiplied by the width of both floats is the total vertical water load. Thus,

$$L=\frac{a\times 2b}{W}\times W.$$

when $a$ = combined area of load rectangles.
$b$ = width of one float = 26 inches.
$W$ = gross weight of seaplane = 2,150 pounds.
$L$ = total vertical water load.

The actual weight is substituted only in the denominator so that $L$ is given in terms of $W$.

The three load distributions of Figure 12 represent the worst conditions of the two pancake landing runs 55 and 56. Case 1 represents the distribution with the high-pressure area under the *c. g.* and was taken from run 56. Cases 2 and 3 were taken from run 55 and represent the distributions when the high pressure is extended over a maximum area in the forebody and when it is near the bow, respectively. The distribution forward in this landing was unusually bad.

The maximum total load thus derived is 6.8 $W$, where $W$ is the weight of the seaplane. The maximum load indicated by the accelerations measured at the *c. g.* is 4.3 $W$. The maximum acceleration was not obtained for run 55 and it is possible that it was slightly greater than the 4.3 $g$ determined in a similar landing. It is likely, however, that the chief cause for the discrepancy is inaccuracy in the assumed load distribution, particularly in the sustained pressure extending from the step to the high-pressure area. A small difference due to flexibility of the structure is also to be considered, and there is a possibility that the load is unequally distributed between the floats. The time at which the maximum accelerations occurred in the pancake landings is in fair agreement with the load distributions shown, as the maxima occurred when the high pressures were well forward. The load distributions are, therefore, probably representative of actual conditions with the exception that the magnitude of the computed total load is possibly somewhat greater than that actually experienced.

The point of application of the resultant force may be determined from the load distributions given, but the direction of the resultant is unknown. It does not pass through the *c. g.* when the resultant is forward as there is considerable angular acceleration. The magnitude of this angular acceleration can not be determined accurately from the float angle records, but the record for pancake landing run 44 shows that it may be as great as 10 radians per second per second. This shows that the resultant must pass considerably forward of the *c. g.*

The load distribution abaft the step can not be determined by the method used for the forebody since no continuous pressure travel curves were obtained. However, the accelerometer at the *c. g.* recorded 1.8 $g$ when the high pressure was abaft the step in pancake landing run 56, and at the same time the float bottom accelerometer exceeded 2 $g$. Stations Q and P both recorded very high pressure in this landing and the resultant load is, therefore, probably applied between these two stations or about 4 feet abaft the step, and is of considerable importance.

## NEGATIVE PRESSURES

Simultaneous values of the negative pressures at intervals during take-off are given in Table III with the corresponding air speed, float angle, and approximate water speed; and in a figure accompanying the table the locations of the pressure orifices are shown. The pressures were read at several intervals from continuous records taken from opening of the throttle to get-away. The intervals were chosen so as to include high pressures throughout the runs and are timed in seconds from the start of the take-off.

At low speeds negative pressures were sustained and existed over a small area extending a few inches abaft the step. At high speeds this area extended back along the keel more than 2 feet, but not along the chine, and the pressures were sharply fluctuating as shown in Figure 13. At intermediate speeds the pressures abaft the step were nearly zero but in some cases there were

small peak pressures at regular intervals corresponding to the period of oscillation of the seaplane. These variations were most noticeable at stations 1, 3, and 4, at which they occurred simultaneously, but the peaks were usually positive at station 3 instead of negative as at 1 and 4. At station 5 the pressure was unusual in that it showed no sharp fluctuations. Forward of the step the pressure was always positive.

The largest negative pressures were recorded at stations 1 and 2 immediately abaft the step and occurred with the control neutral at water speeds of from 9 to 15 M. P. H. The highest value obtained was 0.87 pound per square inch, which is of small structural importance. At high speeds the pressures fluctuated rapidly and there is a possibility that this might cause considerable vibration of the bottom skin.

The negative pressures were influenced by the speed and float angle. One of the forces determining the float angle is the force on the elevators. It was found that with the control held back the sustained negative pressure abaft the step at low speeds was largely eliminated, and that the longitudinal acceleration during take-off was steady. With the control neutral or forward the negative pressure at low speeds was high and sustained for a period of several seconds, during which the acceleration was very slight.

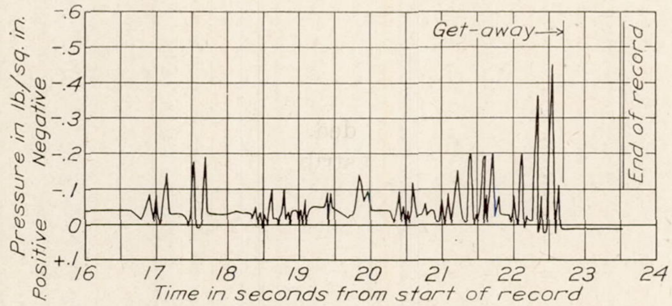



FIGURE 13.—Reproduction of a typical negative pressure record showing rapid fluctuations of pressure near get-away

## DISCUSSION OF RESULTS

It is considered that the maximum pressures obtained were excessive for the TS–1 float, since both floats were damaged during tests and eventually ruined in a landing apparently no worse than others for which records were obtained. The complete failure was probably caused by the repetition of hard landings on floats which had had considerable service. The final failure was in the planking, stringers, and stringer bracing a short distance forward of the step. This indicates a failure due to local pressure which is not necessarily coincident with maximum moment or total vertical load.

Large total loads as well as high local pressures result from pancake landings with large float angle. In addition, the maximum resultant force is well forward of the *c. g.* which imposes a large moment. The direction of this resultant force was not determined because no measurements of the longitudinal components of either force or acceleration were made, but the existence of considerable angular acceleration shows that it does not pass through the *c. g.*

The maximum pressure on the TS–1 was about 10 pounds per square inch and on the UO–1, 6.5 pounds per square inch. High pressures were experienced near the bow of the TS–1 and not on the UO–1. The higher pressures on the TS–1 are probably due to unequal distribution of the load between floats, the generally higher speed, and the smaller angle of V. The speed of the TS–1 for comparative maneuvers is 5 to 10 M. P. H. higher than for the UO–1; and the angle of V is 3° less at the step and 10° less at corresponding positions near the bow. The peak pressure near the bow is probably due to the small angle of V and the gradually rising keel line. It is probably influenced also by the location of the *c. g.*, which is 6 inches farther forward on the TS–1 than on the UO–1 float.

The negative pressures are of small magnitude, and the investigation shows that it is reasonable to neglect pressures abaft the step when considering total loads with a pressure

peak forward of the step. The results indicate a relation between negative pressure and float resistance which is possibly of sufficient importance to warrant a more complete investigation of this relation.

## CONCLUSIONS

The results of this investigation apply only to the TS-1 seaplane as used in these tests. The effect of variations in speed, float shape, and other characteristics likely to be different in other designs is probably considerable on both the magnitude and distribution of pressures.

Maximum pressures as high as 10 pounds per square inch are most likely to occur at the step, but under some conditions of landing, pressures of practically the same magnitude may also occur at the stern and near the bow.

The only part of the float on which no large pressure occurs is a limited area immediately abaft the step in which a maximum negative pressure of 0.87 pound per square inch was measured.

Maximum pressures are always confined to a small area at any instant and last approximately one-twentieth to one-hundredth second at any given location.

Sustained pressures are always small compared to the maximum pressures and are greatest near the step.

The worst distribution of pressures and the greatest accelerations at the *c. g.* occurred in pancake landings and were principally due to the development of a high pressure near the bow.

The negative pressures which exist abaft the step appear to be of small consequence structurally, but may be of sufficient interest in a study of float resistance and trim to warrant a more complete investigation.

A vertical component of acceleration of 4.5 *g* at the *c. g.* is not likely to be exceeded in a safe landing.

Acceleration of the float bottom is probably 1 to 2 *g* greater than that at the *c. g.* in hard landings.

In future investigations of this sort the longitudinal component of acceleration at the *c. g.* should be measured.

LANGLEY MEMORIAL AERONAUTICAL LABORATORY,
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS,
LANGLEY FIELD, VA., *December 28, 1928.*

## REFERENCES AND BIBLIOGRAPHY

Reference 1. Thompson, F. L.: Water Pressure Distribution on a Seaplane Float. N. A. C. A. Technical Report No. 290, 1928.

Reference 2. Norton, F. H. and Warner, E. P.: Accelerometer Design. N. A. C. A. Technical Report No. 100, 1921.

Reference 3. Norton, F. H.: N. A. C. A. Recording Air-Speed Meter. N. A. C. A. Technical Note No. 64, 1921.

Reference 4. Brown, W. G.: The Synchronization of N. A. C. A. Flight Records. N. A. C. A. Technical Note No. 117, 1922.

Baker, G. S. and Keary, E. M.:

Experiments with Full-Sized Machines (2d series). Local Water Pressures on Flying-Boat Hulls. British A. R. C. Reports and Memoranda No. 683, September, 1920.

P-5 Flying Boat N-86, Impact Tests. (Experiments with Full-Sized Machines, 3d series.) British A. R. C. Reports and Memoranda No. 926, April, 1924.

Bottomley, G. H.: The Impact of a Model Seaplane, Float on Water. British A. R. C. Reports and Memoranda No. 583, March, 1919.

Richardson, H. C.: Airplane and Seaplane Engineering. Bureau of Aeronautics, Navy Department Technical Note No. 59, 1923.

Reference 5. Zahm, A. F.: Development of an Airplane Shock Recorder. Journal of the Franklin Institute, August, 1919.

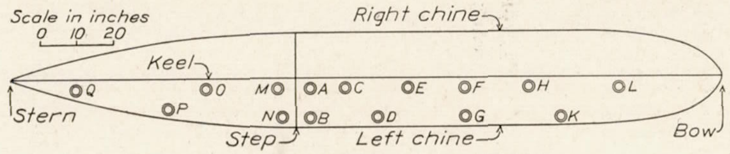
# TABLE I.

## WATER-PRESSURE DISTRIBUTION ON THE TS-1 SEAPLANE FLOAT

[Recorded water pressures in pounds per square inch]

| Run No. | Maneuver | Condition of water | Air speed in M.P.H. | Approximate water speed in M.P.H. | Longitudinal float angle in degrees | Maximum acceleration in terms of g: c.g. | Maximum acceleration in terms of g: Float bottom | Pressure stations: A | | B | | C | | D | | E | | F | | G | | H | | K | | L | | M | | N | | O | | P | | Q | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | a | b | a | b | a | b | a | b | a | b | a | b | a | b | a | b | a | b | a | b | a | b | a | b | a | b | a | b | a | b | |
| 15 | Taxiing—tail down | Smooth | 47–53 | 34–40 | 10–9 | 1.9 | ------ | 4.3 | --- | 5.6 | --- | 5.3 | --- | 4.4 | --- | 3.0 | --- | --- | 2.0 | --- | 1.9 | --- | 1.9 | --- | 1.8 | --- | 1.8 | --- | 2.3 | --- | 2.5 | 2.1 | 3.5 | 2.1 | 2.3 | --- | 2.7 | |
| 18 | do | do | | | | 1.9 | ------ | 6.0 | --- | 9.2 | --- | 6.6 | --- | --- | 5.4 | 5.3 | --- | --- | --- | --- | 3.7 | --- | 3.6 | --- | 3.6 | --- | 3.4 | --- | 5.4 | --- | --- | --- | 5.6 | --- | 5.6 | --- | 6.6 | |
| 23 | do | do | 45–46 | 45–46 | 8 | 1.6 | ------ | 8.7 | 9.1 | 8.8 | 10.5 | 8.2 | 8.6 | --- | 6.4 | --- | 6.2 | --- | 5.7 | --- | 6.3 | --- | 6.1 | --- | 6.2 | --- | 5.8 | --- | 5.2 | --- | --- | --- | --- | --- | 5.5 | --- | 6.4 | |
| 24 | do | do | 43–47 | 43–47 | 9–8 | 1.6 | ------ | 6.7 | --- | 8.0 | --- | 8.0 | --- | --- | 4.7 | --- | 4.6 | --- | 3.3 | --- | 3.5 | --- | 3.4 | --- | 3.4 | --- | 3.2 | --- | 3.7 | --- | --- | --- | --- | 5.2 | --- | --- | 4.7 | |
| 51 | do | Very smooth | 32–33 | 26–27 | | 1.6 | 0–2 | --- | 7.9 | --- | 5.7 | --- | --- | 4.2 | 8.1 | --- | 7.0 | --- | 6.5 | --- | 6.5 | --- | 6.3 | --- | 6.1 | --- | 6.4 | --- | 4.8 | --- | --- | --- | 5.0 | --- | 4.5 | --- | 5.6 | |
| 19 | Taxiing—normal | Smooth | | | 5–2 | 1.7 | ------ | 4.7 | 5.4 | 5.7 | --- | --- | 5.9 | --- | 4.9 | --- | 4.7 | 3.9 | --- | 3.1 | --- | 5.8 | --- | --- | 3.1 | --- | 3.1 | --- | 5.8 | --- | --- | --- | 6.1 | --- | 6.1 | --- | 7.1 | |
| 20 | do | do | | | 4–2 | 1.5 | ------ | 2.8 | 3.5 | 4.8 | 5.5 | --- | 3.9 | 3.4 | 4.0 | 3.0 | 3.9 | 3.0 | --- | 2.7 | 3.2 | 5.1 | --- | --- | 2.4 | --- | 2.3 | --- | 2.7 | --- | --- | --- | 2.5 | --- | 2.9 | --- | 3.4 | |
| 21 | do | 8 to 10 inch waves | 62–64 | 51–53 | 7–5 | 2.6 | ------ | 7.2 | 8.9 | 8.8 | 10.5 | --- | 7.7 | 6.2 | 7.2 | 6.2 | 7.4 | 5.5 | 6.9 | --- | 6.1 | --- | 6.0 | --- | 5.9 | --- | 5.6 | --- | 5.2 | --- | 6.5 | --- | --- | --- | 5.6 | --- | 6.6 | |
| 22 | do | do | 51–55 | 40–44 | 3–2 | 1.7 | ------ | --- | 4.2 | 5.0 | 5.3 | --- | 5.5 | --- | 4.5 | --- | 4.3 | 3.5 | 4.3 | 3.8 | 4.2 | 4.9 | 6.6 | 4.0 | 5.1 | 3.6 | 4.1 | --- | 3.6 | --- | 4.5 | --- | --- | --- | 3.8 | --- | 4.5 | |
| 31 | do | Smooth | 58 | 47 | | | | --- | 5.6 | --- | 7.1 | --- | 7.1 | --- | 6.4 | --- | 7.0 | --- | --- | --- | 6.7 | --- | 7.6 | --- | 7.2 | --- | 6.5 | --- | 5.7 | --- | --- | --- | --- | --- | 6.0 | --- | 6.0 | |
| 48 | do | 12 to 15 inch waves | 58–59 | 41–42 | | 2.4 | 2–4 | --- | 5.0 | --- | 5.1 | --- | 5.5 | --- | 5.6 | --- | --- | --- | 5.9 | --- | 6.1 | 5.9 | 7.3 | --- | 5.6 | --- | 6.0 | --- | 4.6 | --- | --- | --- | 5.0 | --- | 4.8 | --- | 5.2 | |
| 3 | Landing, stalled, power off. | 10 to 12 inch waves | 65–58 | 55–48 | 13–1 | 2.2 | ------ | 7.3 | 8.4 | 7.9 | 9.8 | 7.5 | 10.0 | --- | 6.1 | 5.9 | 6.8 | --- | 3.9 | --- | 4.2 | 4.8 | 7.0 | 6.0 | --- | 6.0 | --- | --- | 4.5 | --- | 4.7 | --- | --- | --- | 4.6 | --- | 5.0 | |
| 5 | do | Very smooth | 65–60 | 60–55 | | | ------ | 5.7 | 6.3 | 6.8 | 8.1 | 6.8 | 7.5 | --- | 5.9 | 5.7 | 6.8 | --- | 4.7 | --- | 5.2 | 5.0 | 5.8 | 5.1 | 5.6 | 6.9 | --- | --- | 5.2 | --- | 6.0 | --- | 5.6 | --- | 5.5 | 6.3 | 7.2 | |
| 6 | do | do | 64–58 | 59–53 | | 2.3 | ------ | 4.8 | --- | 6.1 | --- | 5.9 | --- | 3.4 | 3.7 | 4.0 | 4.5 | 2.2 | 2.5 | 1.8 | 2.3 | 3.8 | --- | --- | 1.6 | --- | 1.6 | --- | 2.3 | --- | 2.6 | --- | 2.0 | --- | 2.3 | 2.7 | 3.3 | |
| 30 | do | Smooth | 53–50 | 42–39 | | 2.4 | ------ | 6.1 | --- | 6.6 | 7.7 | 6.7 | --- | 7.7 | --- | 4.5 | --- | --- | 4.5 | 4.7 | 5.3 | 6.5 | --- | --- | 5.1 | --- | 4.7 | --- | 5.6 | --- | --- | --- | 5.7 | --- | 5.8 | 5.7 | 8.3 | |
| 43 | do | 10 to 12 inch waves | 55–49 | 42–36 | 16–4 | 2.8 | ------ | 7.4 | 9.2 | 9.7 | 10.4 | 7.2 | 9.5 | 6.4 | 7.0 | 7.1 | 8.2 | --- | 6.8 | --- | 6.4 | --- | 7.7 | --- | 6.9 | --- | 6.2 | --- | --- | --- | --- | --- | 4.8 | --- | 5.3 | --- | --- | |
| 47 | do | 12 to 15 inch waves | 56–44 | 39–27 | | 2.9 | 4–6 | 4.9 | 6.0 | 6.0 | 6.7 | 7.1 | 8.0 | 6.6 | 7.6 | --- | --- | --- | 5.8 | --- | 6.0 | 5.8 | 6.7 | --- | 5.5 | --- | 5.8 | --- | 4.9 | --- | --- | --- | 5.3 | --- | 5.2 | 5.6 | 8.4 | Unusually high float angle. |
| 7 | Landing, stalled, power on. | Very smooth | 60–54 | 55–49 | 12–2 | 2.9 | ------ | 8.9 | --- | 8.4 | 10.1 | 7.9 | 8.4 | --- | 6.1 | 6.0 | 7.1 | --- | 4.7 | --- | 5.2 | 5.0 | 5.8 | --- | 5.2 | --- | 4.8 | --- | 5.2 | --- | 6.0 | --- | 5.6 | --- | 5.5 | --- | 6.3 | |
| 8 | do | do | 56 | 47 | | 2.4 | ------ | 5.0 | --- | 5.1 | 6.2 | 4.2 | 4.9 | 3.5 | 3.8 | 3.4 | 4.0 | 3.3 | 3.8 | --- | 2.6 | 2.6 | 3.5 | --- | 2.5 | --- | 2.5 | --- | 2.7 | --- | 3.2 | --- | 2.6 | --- | 2.9 | --- | 3.3 | |
| 13 | do | Smooth | 66–65 | 53–52 | 11–3 | 1.9 | ------ | 6.1 | --- | 6.2 | 7.4 | 5.7 | 6.0 | --- | 4.3 | 4.2 | 5.2 | 2.8 | 3.4 | 2.8 | 3.1 | 5.5 | --- | --- | 2.8 | --- | 2.7 | --- | 3.0 | --- | 3.5 | --- | 2.9 | --- | 3.1 | --- | 3.6 | |
| 17 | do | do | | | 13–2 | 2.0 | ------ | 7.0 | 8.4 | 7.1 | 8.6 | --- | 7.5 | --- | 6.2 | 6.1 | 7.3 | --- | 5.6 | --- | 6.0 | --- | 5.9 | --- | 6.0 | --- | 5.7 | --- | 5.2 | --- | --- | --- | 5.3 | --- | 5.3 | --- | 6.1 | |
| 9 | Landing, fast | Very smooth | 78–75 | 78–75 | | 3.2 | ------ | 8.4 | --- | 8.0 | --- | 7.5 | 8.0 | --- | 5.9 | 5.7 | 6.8 | 6.4 | 7.0 | --- | 5.6 | 6.4 | --- | --- | 5.8 | --- | 4.9 | --- | 5.1 | --- | 5.8 | --- | 5.5 | --- | 5.3 | --- | 6.0 | Cracked bottom of right float at step. |
| 10 | do | 12 to 15 inch waves | 71 | 49 | 9–2 | 2.3 | ------ | 4.2 | --- | 4.5 | --- | 4.1 | 5.2 | 3.9 | --- | 2.9 | 3.6 | 2.0 | 2.5 | 1.9 | --- | --- | 1.9 | --- | 1.8 | --- | 1.8 | --- | 2.0 | --- | 2.3 | --- | 1.7 | --- | 2.0 | --- | 2.4 | |
| 11 | do | do | 73–72 | 51–50 | 9–3 | ---- | ------ | 5.7 | 6.9 | 6.0 | 7.2 | 5.7 | 6.9 | 5.2 | 5.8 | --- | 5.0 | 5.2 | 5.6 | 4.4 | 5.1 | 4.4 | 5.3 | 4.5 | --- | 4.2 | --- | --- | 4.6 | --- | 5.3 | --- | 4.8 | --- | 4.7 | --- | 5.4 | |
| 12 | do | do | 75–72 | 73–70 | 9–3 | 3.0 | ------ | 6.0 | 6.9 | 7.1 | 8.5 | --- | 7.5 | 6.3 | 7.2 | --- | 6.1 | --- | 5.2 | --- | 5.6 | 5.5 | 6.4 | --- | 5.2 | --- | 4.9 | --- | 5.0 | --- | 5.6 | --- | 5.2 | --- | 5.0 | --- | 5.8 | |
| 44 | Landing, pancake | 10 to 12 inch waves | 50–48 | 37–35 | 16–3 | 4.3 | ------ | 5.7 | --- | 7.1 | --- | 5.7 | --- | 4.2 | --- | 5.0 | 5.4 | --- | --- | 2.4 | 3.0 | 4.1 | --- | --- | --- | 3.0 | --- | --- | --- | --- | --- | --- | 2.3 | 2.7 | 3.5 | --- | --- | Cracked bottom at station B in this or a similar landing following it. |
| 55 | do | Very smooth | 50–45 | 47–42 | | ---- | 4–6 | 7.9 | 9.2 | 5.7 | 8.1 | --- | --- | 8.2 | 9.7 | 7.0 | --- | 6.3 | --- | 6.2 | 7.9 | 6.0 | 7.5 | 5.8 | 6.6 | 8.8 | --- | --- | 4.6 | --- | --- | --- | 4.9 | --- | 4.9 | 8.4 | --- | Landing similar to run 44. |
| 56 | do | do | 51 | 48 | | 3.8 | 2–4 | 8.9 | --- | 7.7 | --- | --- | --- | 7.9 | --- | 6.7 | --- | 6.4 | --- | --- | 6.4 | --- | 6.2 | --- | 5.9 | 6.3 | 7.2 | --- | 5.0 | --- | --- | 5.9 | --- | 8.2 | --- | 9.7 | --- | Do. |
| 41 | Porpoising | Smooth | 44–36 | 31–23 | 5–14 | 2.1 | ------ | --- | 5.3 | --- | 6.9 | --- | 7.0 | --- | 6.4 | --- | 7.0 | --- | 6.8 | --- | 6.4 | --- | 7.7 | --- | 6.9 | --- | 6.2 | --- | --- | --- | --- | --- | 5.0 | --- | 5.6 | --- | --- | |
| 42 | do | do | 39–40 | 26–27 | 2–10 | 2.1 | ------ | 3.5 | --- | 5.1 | --- | 3.5 | --- | 2.5 | 2.8 | 3.1 | --- | 1.9 | 2.1 | 2.9 | --- | 3.5 | --- | 2.3 | --- | 2.4 | --- | --- | --- | --- | --- | --- | 2.5 | --- | 2.8 | --- | --- | |
| 53 | do | Very smooth | | | | 2.1 | 2–4 | --- | 6.5 | 4.6 | 6.4 | --- | --- | 3.5 | 6.8 | 5.5 | 9.5 | 3.8 | 6.8 | 3.8 | 4.9 | 3.4 | 4.2 | 3.7 | 4.3 | 3.7 | 4.2 | --- | 3.5 | --- | --- | --- | 3.6 | --- | 3.6 | --- | 4.1 | |
| 54 | do | do | | | | 1.6 | 0–2 | 4.7 | 5.1 | 4.0 | --- | --- | --- | 5.2 | 6.4 | 3.4 | 6.8 | 2.2 | 4.6 | 2.3 | 3.4 | 2.3 | 3.0 | 2.5 | 3.1 | --- | 2.2 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | |

a=pressure exceeded. b=pressure not exceeded.




Location of pressure stations in the TS-1 float

## TABLE II

SUMMARY OF FIVE HIGHEST PRESSURES AT ALL STATIONS

Pressure stations

| A | | B | | C | | D | | E | | F | | G | | H | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run No. | $p$ | Run No. | $p$ | Run No. | $p$ | Run No. | $p$ | Run No. | $p$ | Run No. | $p$ | Run No. | $p$ | Run No. | $p$ |
| 7 | 9.7 | 43 | 10.3 | 3 | 8.9 | 55 | 9.2 | 43 | 7.9 | 56 | 7.2 | 55 | 7.3 | 30 | 7.3 |
| 6 | 9.7 | 18 | 10.0 | 24 | 8.8 | 56 | 8.7 | 55 | 7.8 | 55 | 7.1 | 30 | 5.3 | 9 | 7.2 |
| 3 | 9.2 | 21 | 9.9 | 23 | 8.7 | 30 | 8.5 | 56 | 7.5 | 9 | 7.0 | 11 | 5.0 | 55 | 7.0 |
| 9 | 9.2 | 23 | 9.9 | 43 | 8.6 | 47 | 7.4 | 21 | 7.1 | 21 | 6.5 | 53 | 4.6 | 48 | 6.9 |
| 5 | 8.8 | 7 | 9.5 | 7 | 8.4 | 43 | 7.0 | 17 | 7.0 | 11 | 5.7 | 22 | 4.3 | 47 | 6.5 |

| K | | L | | M | | N | | O | | P | | Q | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run No. | $p$ | Run No. | $p$ | Run No. | $p$ | Run No. | $p$ | Run No. | $p$ | Run No. | $p$ | Run No. | $p$ |
| 3 | 6.8 | 55 | 9.6 | ------ | ------ | ------ | ------ | 56 | 6.7 | 56 | 9.0 | 56 | 10.5 |
| 55 | 6.5 | 5 | 7.7 | ------ | ------ | ------ | ------ | 15 | 2.9 | 24 | 6.0 | 55 | 9.2 |
| 5 | 5.6 | 56 | 7.0 | ------ | ------ | ------ | ------ | ------ | ------ | 44 | 3.4 | 5 | 7.2 |
| 11 | 5.3 | 3 | 6.8 | ------ | ------ | ------ | ------ | ------ | ------ | 15 | 2.4 | 30 | 6.8 |
| 22 | 4.8 | 11 | 5.0 | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | 47 | 6.7 |

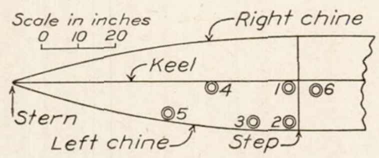
$p$ = mean pressure corrected for acceleration in pounds per square inch. Acceleration correction is $+\frac{1}{4}$ pound per square inch, as explained in text. Spaces left blank indicate that no pressure was recorded.

## TABLE III

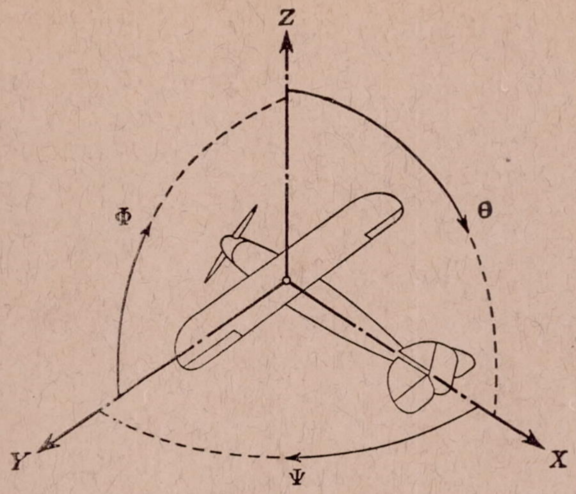
### NEGATIVE WATER PRESSURES ON THE TS-1 SEAPLANE FLOAT

| Maneuver | Run No. | Time in seconds | Pressure in pounds per square inch. Orifice Nos. | | | | | | Air speed in M. P. H. | Approximate water speed in M. P. H. | Float angle in degrees | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | | | | |
| Take-off, control back | 69 | 6 | 0.01 | ------ | 0.02 | 0.01 | 0 | ------ | 36 | 36 | 9 | |
| | | 7¾ | .11 | ------ | + | .21 | + | ------ | 42 | 42 | 10-6 | |
| | | 10⅞ | .28 | ------ | + | .32 | + | ------ | 50 | 50 | 10-7 | |
| | | 12⅞ | .26 | ------ | + | .39 | + | ------ | 53 | 53 | 8-5 | |
| | | 14⅛ | .01 | ------ | .32 | .01 | + | ------ | 55 | 55 | 7-5 | Get-away at 15½ seconds. |
| Do | 74 | 3 | .13 | 0.42 | + | ------ | ------ | + | 20 | 6 | 7 | |
| | | 3⅜ | .16 | .19 | + | ------ | ------ | + | 22 | 8 | 9 | |
| | | 3¾ | .01 | .06 | .08 | ------ | ------ | + | 23 | 9 | 10 | |
| | | 8⅝ | .31 | .14 | .03 | ------ | ------ | + | 38 | 24 | 10-8 | |
| | | 13½ | .34 | .34 | 0 | ------ | ------ | + | 53 | 39 | 10-6 | Get away at 14 seconds. |
| Do | 75 | 2⅛ | .11 | .44 | + | ------ | ------ | + | 22 | 8 | 6 | |
| | | 2½ | .23 | .25 | + | ------ | ------ | + | 23 | 9 | 7 | |
| | | 2¾ | + | .06 | + | ------ | ------ | + | 23 | 9 | 7 | |
| | | 3 | 0 | .10 | 0 | ------ | ------ | + | 23 | 9 | 8 | |
| | | 7¾ | .19 | .16 | + | ------ | ------ | + | 37 | 23 | 9-7 | |
| | | 8⅛ | .31 | .16 | 0 | ------ | ------ | + | 37 | 23 | 9-7 | |
| | | 10⅞ | .39 | .34 | .02 | ------ | ------ | + | 46 | 32 | 10-6 | |
| | | 12¼ | .39 | .42 | + | ------ | ------ | + | 51 | 37 | 9-7 | Do. |
| Take-off, control neutral | 70 | 4 | .35 | ------ | + | + | + | ------ | 20 | 9 | 5 | |
| | | 4⅔ | .14 | ------ | .13 | + | + | ------ | 22 | 11 | 6 | |
| | | 5 | .01 | ------ | .04 | .01 | + | ------ | 22 | 11 | 6 | |
| | | 16 | .03 | ------ | .14 | .01 | 0 | ------ | 53 | 42 | 3 | |
| | | 20¼ | .46 | ------ | + | .58 | + | ------ | 55 | 44 | 7-5 | Get-away at 24 seconds. |
| Do | 71 | 3⅝ | 0.57 | ------ | + | + | + | ------ | 23 | 12 | 4 | |
| | | 4⅝ | .39 | ------ | 0.28 | + | + | ------ | 23 | 12 | 4 | |
| | | 5½ | .05 | ------ | .04 | 0.03 | + | ------ | 23 | 12 | 5 | |
| | | 13 | ------ | ------ | ------ | .04 | 0 | ------ | 46 | 35 | 2-4 | |
| | | 19⅛ | ------ | ------ | ------ | .36 | .01 | ------ | 54 | 43 | 2-4 | Get-away at 23½ seconds. |
| Do | 76 | 3⅞ | .87 | .70 | + | ------ | ------ | + | 23 | 9 | 3 | |
| | | 4⅝ | .39 | .83 | + | ------ | ------ | + | 27 | 13 | 5 | |
| | | 5⅜ | .26 | .24 | .16 | ------ | ------ | + | 27 | 13 | 5 | |
| | | 6 | .18 | .18 | .12 | ------ | ------ | + | 28 | 14 | 5 | |
| | | 6¼ | .05 | .08 | .01 | ------ | ------ | + | 28 | 14 | 6 | |
| | | 17¾ | .19 | .16 | .16 | ------ | ------ | + | 57 | 43 | 3 | Get-away at 22½ seconds. |
| Do | 77 | 2⅞ | .53 | .77 | + | ------ | ------ | + | 24 | 10 | 4 | |
| | | 5¼ | .27 | .77 | + | ------ | ------ | + | 28 | 14 | 3 | |
| | | 5½ | .53 | .64 | + | ------ | ------ | + | 29 | 15 | 3 | |
| | | 9½ | .27 | .32 | .16 | ------ | ------ | + | 30 | 16 | 4 | |
| | | 11¾ | .23 | .28 | .20 | ------ | ------ | + | 30 | 16 | 4 | |
| | | 12½ | .05 | .07 | .05 | ------ | ------ | + | 30 | 16 | 5 | |
| | | 14 | .03 | .07 | .03 | ------ | ------ | + | 30 | 16 | 6 | |
| | | 22⅛ | .37 | .32 | .01 | ------ | ------ | + | 52 | 38 | 3-6 | |
| Take off, control forward | 72 | 5 | .50 | ------ | + | + | + | ------ | 23 | 12 | 5 | |
| | | 5⅞ | .25 | ------ | .22 | + | + | ------ | 24 | 13 | 3 | |
| | | 7½ | .05 | ------ | .09 | .03 | + | ------ | 25 | 14 | 4 | |
| | | 16¼ | .05 | ------ | .11 | .05 | 0 | ------ | 42 | 31 | 5-1 | |
| | | 24⅓ | .37 | ------ | + | .55 | + | ------ | 54 | 43 | ---------- | Get-away at 26½ seconds. |

+=positive pressure.




Location of negative pressure orifices in the TS-1 float




Positive directions of axes and angles (forces and moments) are shown by arrows

| Axis | | Force (parallel to axis) symbol | Moment about axis | | | Angle | | Velocities | |
|---|---|---|---|---|---|---|---|---|---|
| Designation | Symbol | | Designation | Symbol | Positive direction | Designation | Symbol | Linear (component along axis) | Angular |
| Longitudinal | $X$ | $X$ | rolling | $L$ | $Y \longrightarrow Z$ | roll | $\Phi$ | $u$ | $p$ |
| Lateral | $Y$ | $Y$ | pitching | $M$ | $Z \longrightarrow X$ | pitch | $\Theta$ | $v$ | $q$ |
| Normal | $Z$ | $Z$ | yawing | $N$ | $X \longrightarrow Y$ | yaw | $\Psi$ | $w$ | $r$ |

Absolute coefficients of moment

$$C_L=\frac{L}{qbS}\ C_M=\frac{M}{qcS}\ C_N=\frac{N}{qfS}$$

Angle of set of control surface (relative to neutral position), $\delta$. (Indicate surface by proper subscript.)

## 4. PROPELLER SYMBOLS

$D$, Diameter.
$p_e$, Effective pitch
$p_g$, Mean geometric pitch.
$p_s$, Standard pitch.
$p_v$, Zero thrust.
$p_a$, Zero torque.
$p/D$, Pitch ratio.
$V'$, Inflow velocity.
$V_s$, Slip stream velocity.

$T$, Thrust.
$Q$, Torque.
$P$, Power.
(If "coefficients" are introduced all units used must be consistent.)
$\eta$, Efficiency $= T\ V/P$.
$n$, Revolutions per sec., r. p. s.
$N$, Revolutions per minute., R. P. M.
$\Phi$, Effective helix angle $=\tan^{-1}\left(\frac{V}{2\pi rn}\right)$

## 5. NUMERICAL RELATIONS

1 HP = 76.04 kg/m/sec. = 550 lb./ft./sec.
1 kg/m/sec. = 0.01315 HP.
1 mi./hr. = 0.44704 m/sec.
1 m/sec. = 2.23693 mi./hr.

1 lb. = 0.4535924277 kg.
1 kg = 2.2046224 lb.
1 mi. = 1609.35 m = 5280 ft.
1 m = 3.2808333 ft.